A COMPARISON OF NATURAL CONTROL OF TOXOPTERA GRAMINUM IN SOUTH AFRICA AND THE UNITED STATES.

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During the past year, the author, while engaged as Lecturer in Entomology at the Potchefstroon School of Agriculture, spent considerable time in studying Toxoptera graminum in South Africa and its control there by natural enemies. As the results obtained have been somewhat different from those obtained in the United States, it is thought that a comparison of the conditions and the results would be of interest to Entomologists.

Toxoptera graminum is found over certain large areas in South Africa but attracts the greatest amount of attention in the Orange Free State, Basutoland, and the western portion of the Transvaal. It seems to have been present, at least in the Free State, for many years, since the older farmers can remember the pest as long as they have been farming in the eastern portion of the Free State, known as the Conquered Territory. The earliest definite record was 1896, which year is distinctly remembered by a farmer who lost his entire wheat crop in that year. In the higher portions of South Africa, i. e., an elevation of more than 5000 feet, Toxoptera is either not present or is not present in numbers sufficient to attract the attention of the farmer. In the lower coastal regions, it also appears to be absent as, for example, along the coastal region of Natal. It is probable that the increased importance of Toxoptera during later years has been due to the destruction of the locusts which formerly swarmed over South Africa. There is little doubt but that the locusts destroying the grain and incidentally destroying Toxoptera were responsible for the prevention of what might have been a serious attack during that year. Since the locusts have been destroyed, Toxoptera has had a better opportunity of showing the injury of which it is capable.

In South Africa, there seem to be two forms of Toxoptera under normal conditions, namely, the winged migratory females and the apterous, viviparous females, the males and the

oviparous females apparently being absent. As these forms are too well known to entomologists to require a description, only a few notes concerning their migration and food plants will be given.

Toxoptera, during the summer time, from about the middle of November until March, live upon various grasses and volunteer grain plants. The most important grasses in this connection are Johnson's Grass (Sorghum halepense), Goose Grass (Eleusione indica), Sweet Grass (Panicum laevifolium), Teff, Millet, Indian Corn, and Kaffir Corn (Sorghum Sp.). The Blue Grass, upon which it is found so frequently in the Free State, is not Andropogon hirtus, as reported by C. B. Van der Merve and mentioned by F. M. Webster, but is the Sweet Grass Panicum laevifolium, which is usually called Blue Grass in the Free State and Sweet Grass in the Transvaal. There are a number of grasses in South Africa known as Blue Grass, without a distinctive common name. From March until June or July, Toxoptera is found upon green forage crops such as barley, rye, and oats. These give it an opportunity to exist from the time that the grass becomes too old for it, or is killed by the frost, until the main grain crop of the year is up, about June or July. It is also very abundant during the winter time upon Rescue Grass (Bromus willdenowii).

It exists on the winter grain until about September or October when it changes to its summer host plants. The severe attack usually occurs either in March on the green forage crops or in July, August, or September, on the main grain crops. The most critical time of the year for Toxoptera in South Africa is in October or November, when it becomes necessary to change from the grain field to its summer grasses. The winters in South Africa are dry and, if rains do not occur before October or November, the summer grasses do not come up, while, on the other hand, the grain rapidly ripens, becoming unfavorable for Toxoptera. At such a time, no doubt, large numbers of Toxoptera are lost in making this change. Some of these are always saved by their ability to live upon the roots and underground shoots of Johnson's Grass where they are attended by a common, grayish-brown ant, *Plagiolepsis dustodiens*. This is interesting, inasmuch as H. Maxwell-Lefroy, Government Entomologist of British India, reports Toxoptera

graminum seeking shelter in the depths of the grass roots. They were found in this situation in South Africa in many cases all through the summer, probably thus obtaining some protection from the hot rays of the sun. The forms on the roots were quite white but when such were removed to wheat plants in the Insectary, either they or their off-spring assumed their natural color and it was found that the colonies on the roots tended by the ants consisted of both Toxoptera graminum and also Aphis maidis. These two species were also frequently found associated upon the summer grasses, especially Panicum laevifolium, Indian Corn, and Kaffir Corn.

As to the rate of reproduction of Toxoptera in South Africa, it might be stated that it is about the same as it is in the United States. In South Africa, migrations over large areas as reported in the United States, are not so apt to occur. Similar migrations on a smaller scale, however, do occur. Usually, it is from the dryer portions to the wetter portions of the country, inasmuch as Toxoptera will kill the grain sooner, under dry conditions. There have been no reports of extensive migrations in the Transvaal but they are known in the eastern districts of the Orange Free State. Farmers about Ficksburg, O. F. S., state that the swarms occur coming from the west late in September or October. As the natives of Basutoland do not raise grain for green forage crops, and as the grass is always dead long before the winter grain comes up, most of the Toxoptera injuring the grain in Basutoland must come by migrations from the Orange Free State. It is difficult to get any definite data on this point from the natives but they seem to know that something of the sort occurs.

In South Africa, two internal parasites have been found which are capable of breeding in Toxoptera. The first (Aphidius phorodontis (?) is commonly bred from Toxoptera in the field. Another species is Diaeretus rapæ and has been bred in the field from both the Cabbage Aphis (Aphis brassicæ) and the Green Peach Aphis (Myzus persicæ), both occurring upon cabbages but in the Insectary this species was also bred into Toxoptera. It is doubtful, however, whether this species would normally be found breeding in the field upon Toxoptera unless the grain field was quite close to a cabbage patch. Aphidius phorodontis has been bred from the Green Peach Aphis

(Myzus persicæ), the Black Peach Aphis (Aphis persicæ-niger), the Corn Leaf Aphis (Aphis maidis), Yellow Aphis on Milkweed (Aphis nerii), a reed Aphis (Hyalopterus arundinis) and the Black Bean Aphis (Aphis rumicis).

Aphidius phorodontis, however, seems to be capable of destroying just as many individuals of Toxoptera as is Aphidius testaceipes. The average period of development from egg to adult seems to be about ten to twenty days. The maximum number developed from one female was 286 which is only 15 below the maximum obtained by Mr. Parks in the United States Department of Agriculture. It is safe to assume that in "stinging" so many that it must often occur that two or more eggs are laid in one individual Toxoptera so that it is safe to assume that Aphidius phorodontis lays 300 or 400 eggs. There seem to be about 70 per cent. of the parasites females if the mother Aphidius has been fertilized. It was also shown that one male would fertilize more than one female but time did not permit of finding how many females might be fertilized by one male. If the female was not fertilized, she would lay eggs and the proportion of the parthenogenetic off-spring were about 70 per cent. males.

When an infested grain field is examined, even though species of Aphidius are present, one never finds a large number of parasitized forms of Toxoptera upon a weak plant such as is shown to be the case in the United States. Probably one wheat plant would, at the most, not have more than ten parasitized forms upon it. Besides this species of Aphidius, there are three different species of ladybirds which play an important part in controlling Toxoptera in South Africa. The first and most important is the Black Spotted Ladybird (Adalia flavomaculata), the Red Spotted Ladybird (Chilomenes lunatus), and the Black Ladybird (Exochomus nigromaculatus). These ladybirds are a most important factor in controlling Toxoptera. It is seldom that one finds a field badly infested in which ladybirds are not present and rapidly destroying Toxoptera. The life history of Adalia flavomaculata was worked out rather completely.

Under favorable climatic conditions, the eggs hatched in from five to seven days from the time they were laid. The larvæ feed for a short time upon the eggshells but soon begin feeding

upon the Aphids. The larval stage lasts from about ten to thirteen days during which time they eat, on an average, 320 Toxoptera per larva,—that being about 26 to 28 Toxoptera per day. The pupal stage lasts six to 10 days and about 30 to 35 days elapses from the time that they emerge until they lay eggs. During this time, they eat about 825 Toxoptera per ladybird, making an average of about twenty-five per day to each ladybird.

In this species, all the eggs seemed to be laid during one period which lasted for about a week to ten days, during which time they laid about 100 to 150 eggs. After having completed the egg-laying, they live for some time before they die. The Adalia seems to live about three to four months,—the males dying first. In one experiment, the larvæ were hatched from eggs laid on the 10th of October, 1912, the last ladybird died on the 24th of February, 1913, and the average number of Toxoptera destroyed was 2844 per ladybird. In this experiment, the ladybirds were given as many Aphids as they could eat. When the Aphids were scarce, the ladybirds would not pass as rapidly through the different stages and the number of eggs laid by the adults had a direct bearing upon the quantity of food present. When the food supply runs short, the eggs which have already been laid will be eaten while even the larva will eat each other and the adults will eat the larvæ.

In the case of the Red Spotted Ladybird, we have a larger species, being about 3-10 inches in length and nearly as wide,—hemispherical in shape. The adult ladybird of this species will lay from 150 to 250 eggs during her life. The egg-laying period seems to be divided into several different stages. In feeding experiments with the larvæ of this ladybird, it was found that during the ten days of its larval existence, each larva eats about 440 Aphids. Another interesting point is that the normal life of the Red Spotted Ladybird is much longer than that of the Black Spotted,—being about four to six months.

Both of these ladybirds were found to be parasitized by a species of Dinocampus. The parasite laid its eggs in the larva and in some cases, probably, in the pupa. The cocoon of the parasite is formed underneath the adult ladybird and it seems that the ladybird always reaches the adult stage before the larva of the parasite emerges from the ladybird's body to form

its cocoon. This species of Dinocampus seems to consist entirely of females, as no males were found, even though individuals were bred from females in the Insectary.

The third species of ladybird is much smaller than either of the other two but has a life-cycle similar to the others. No exact records were obtained as to the number of Aphids eaten but it was found that the average life, from the egg until the adult dies is about five to six months. One peculiarity noted was that the eggs were not laid on end as is generally the case with ladybirds, but rested on their sides on the leaf in little heaps. This little ladybird is very severely parasitized by a Chalcid belonging to the genus Homalotylus. The parasite is usually bred from the larva collected in the field. In the month of October, about 25% of the larvæ seemed to be parasitized. From three to seven eggs are laid by the parasite in one larva and the ladybird larva usually hangs itself up as though about to pupate before dying. The larva of the parasite pupates in the dead body of the ladybird larva.

This Chalcid will also breed in captivity in both the other species of ladybird, but has not been bred from either of them in the field.

The little Black Ladybird is most beneficial during the spring and autumn when the cold affects the parasite more than it does the ladybird. During the summertime the ladybird becomes more or less rare, no doubt due to the parasite effectively controlling it.

The ladybirds seem to be of greater value in controlling Toxoptera in South Africa than in the case with the ladybirds which feed upon Toxoptera in the United States. The fact that Aphidius does not immediately destroy Toxoptera but allows it to live for a few days, during which time, if the Toxoptera is an adult, it will produce young, detracts from the value of Aphidius, when compared with the ladybirds. An example will show better what is meant. Take a plant with 200 Aphids, 50 adults and 150 young, under control conditions and introduce a female parasite. There is then a possible chance that all the Aphids on this plant will have an egg laid in them but this will not always happen, inasmuch as two or more eggs would be laid in one Toxoptera while others would escape the parasite. Granting, however, that all of them contained eggs and would

die in about seven days, it is found that the fifty adults would have produced about 500 young during the first two or three days after the egg of the parasite had been laid in their bodies. These young would have a very small chance of being destroyed by the parasite and would reach maturity after the death of their mothers or about three or four days before the offspring of the Aphidius which had "stung" the 200 Aphids, had emerged. During these three or four days, they would be producing young, so that when the Aphidius emerged, there would be between 2000 and 2500 Toxoptera on the plant.

When the offspring of this female parasite emerged, however, the chances are that all the Toxoptera would be destroyed. From the above, it will be seen that starting with one Aphidius and 200 Toxoptera on one plant, there would be at the end of about fourteen days, 2000 or 2500 Toxoptera, while the plant would not be entirely clean of Toxoptera until about twenty days had elapsed. On the other hand, if an adult ladybird had been introduced with the 200 Toxoptera, every individual would have been cleaned away from the plant in ten days at the most, while it probably would have been within five or six days. When the ladybirds are present in the field with Aphidius, another fact must be remembered, namely, that if Aphidius has "stung" a number of Toxoptera and a ladybird later ate these parasitized Toxoptera, the ladybird is also destroying the parasites as well as the Toxoptera. This is even carried further by the ladybirds, inasmuch as they will eat the parasitized forms even when the Toxoptera is dead, and the parasite is in the pupal stage. It is no doubt due to this reason that one does not find wheat plants covered with parasitized forms in the field in South Africa, as one does in the United States. When a number of infested wheat plants were enclosed with wire netting so that Aphidius could gain entrance, but a larger insect, as a ladybird could not, it was soon found that the wheat plants were crowded with parasitized forms similar to those described by Webster as occurring in the United States. There seems to be but little doubt that in South Africa, the ladybirds are of more value in combating Toxoptera than Aphidius. This is of particular interest inasmuch as an attempt is now being made to introduce *Aphidius testaceipes* into British East Africa where Toxoptera is found near Njora.

If *Adalia flavomaculata* and *Chilomenes lunatus* are found there, it is very doubtful whether the value of *Aphidius testaceipes* will be as great as it is in the United States.

The Little Black Ladybird, *Exochomus nigro-fasciatus*, is reported from the Soudan and it, no doubt, occurs in British East Africa. Several Aphid-eating Ladybirds have also been reported from the Soudan as being particularly beneficial in controlling an Aphid on Kaffir Corn.

Another point in favor of the ladybirds is that they will breed and will control Toxoptera at a lower temperature than Aphidius. All the stages are greatly retarded, however, by cold and the adults do not seem to lay eggs. It seems from experiments carried out that more Aphids are required per ladybird in their lives when it is cold than is the case at a warmer temperature. Larvæ of Adalia lived for about thirty-five days at a mean daily temperature of from 45 to 55 degrees and ate during that time 416 Aphids per larva, as compared with 319 in the summer time in a period of thirteen days. At a lower temperature, therefore, the larva eats only about half the number of Aphids per day, but feeds for about 2¾ times as many days.

Besides the ladybirds, one finds a Syrphid Fly (*Xanthogramma scutellare*) does considerable good in controlling Toxoptera. The Syrphid also incidentally destroys Aphidius by destroying Toxoptera which contain the eggs or larvæ of Aphidius. In no case, however, were they found destroying the parasitized forms of Toxoptera. A leaf which has been cleaned by Syrphid Fly larva will be found to have a few parasitized forms of Toxoptera remaining on it. This, however, would not be the case if the leaf had been cleaned by a ladybird or a ladybird's larva.

This Syrphid Fly is also retarded in its good work by a parasite Bassus laetatorius. This parasite very effectively controls the Syrphid Fly when the latter becomes very abundant in the field. The most beneficial work of this Syrphid was found to be in fields which were just becoming infested with Toxoptera migrating from some other place. This Syrphid seems to be the first to find the Aphids in their new home and commence the work of destruction, but as soon as the

Syrphids become overly abundant in the field, the parasites find them and they so reduce their number that they are of very little value.

In conclusion, it might be stated that the cause of a bad outbreak of Toxoptera in South Africa is due to the same causes as a bad outbreak in the United States. If the early winter months are abnormally cold, while the middle months of the winter are warmer than the average, followed again by a cold spring, there is a long period of from five to six months during which time Toxoptera breeds more rapidly than the ladybirds or Aphidius, the result being a bad outbreak of Toxoptera.

Another factor which sometimes tends to cause bad outbreaks is long periods of drought since, under such conditions, plants are not able to withstand the number of Toxoptera which normally they could carry without showing any ill effects, thus dying, not entirely from injury by Toxoptera, but, with drought as a secondary factor. If such land be irrigated, the plants are enabled to survive the attack.